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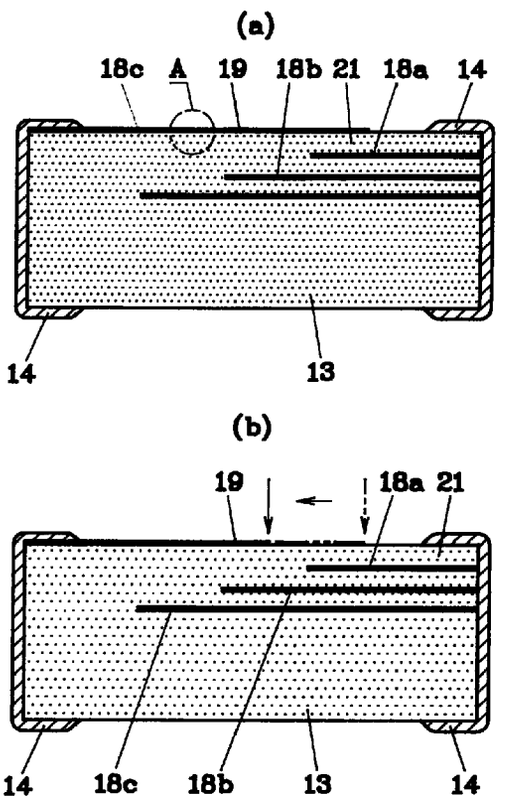
## (54) Laminated capacitor and trimming method thereof

(57) In a laminated capacitor, a plurality of internal electrodes (18a), (18b), (18c) formed within a naked laminated body (13) are opposing to a trimming electrode (19) formed on a surface of the naked laminated body (13) so as to obtain electrostatic capacity, and the plurality of internal electrodes (18a), (18b), (18c) differ from one another in an area opposing to the trimming electrode (19). By removing the trimming electrode (19), from a portion where it is opposing to the more of the internal electrodes (18a), (18b), (18c) toward another portion where it is opposing to the less of the internal electrodes (8a),(18b), (18c), a rate of decreasing in the electrostatic capacity with respect to the area of the trimming electrode (19) is large in an initial stage of the trimming process, and it gradually reduces in accordance with progress thereof. Further, when the electrostatic capacity becomes to be small too much by the trimming, an adjusting layer (21) between the trimming electrode (19) and the internal electrode (18) is deoxidized in a part thereof, thereby the portion of the adjusting layer (21) being turned into conductive so as to increase the electrostatic capacity thereof.

*Fig1*

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## Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a laminated capacitor including external electrodes attached at both edge portions of a principal or naked laminated body and a method of such the capacitor for adjusting electrostatic capacity thereof by trimming, and in particular to a trimming method for a laminated ceramic capacitor for use in such a resonance circuitry requiring a finely adjusted value of the electrostatic capacitance.

2. DESCRIPTION OF RELATED ART

Most of laminated capacitors are made of chip-like naked ceramic bodies of a prism and plate shapes, on both edge surfaces of which are attached with terminals for electrical connection, i.e., external electrodes. Among circuit parts of such the laminated type, in particular, the laminated capacitor for use in the resonance circuit and a filter, etc., is finely and accurately adjusted in characteristics thereof, by means of, so-called a functional trimming, after it is mounted on a circuit board, especially for adjustment of the frequency characteristic thereof.

Fig. 8 attached shows a laminated ceramic capacitor disclosed in Japanese Patent Laying-Open No. Hei 7-183162 (1995), and it is one of such the laminated ceramic capacitors to be adjusted in the capacitance thereof by the trimming as mentioned in the above.

This laminated capacitor has at least a pair of internal electrodes 3 and 3 confronting to each other within the naked laminated body 1 of a ceramic laminated body, and those internal electrodes 3 and 3 are extended out at the edge surfaces of the naked laminated body 1. And, the external electrodes 2 and 2 are formed at the edge portions of the naked laminated body 1. The naked laminated body 1, being under the condition that it is separated from those external electrodes 2 and 2, is formed with a trimming electrode 4 on a surface thereof.

With this capacitor, it can be represented by an equivalent circuit of a series connection of capacities which are formed among the pair of internal electrodes 3 and 3 and the trimming electrode 4. This capacitor is designed and produced in such a manner that it has an electrostatic capacitance being a little bit larger than a predetermined value, and the capacitance is adjusted to decrease down by gradually removing the trimming electrode 4 with irradiation of a laser beam, i.e., by reducing opposing area defined between the trimming electrode 4 and the internal electrode 3, after it is mounted on the circuit board. Thereby, the capacitance is so adjusted that the resonance frequency is fitted within a predetermined boundary value.

Fig. 9 shows a trimming method of the laminated ceramic capacitor shown in Japanese Patent Laying-Open No. Hei 7-45469 (1995).

Among layers of the naked laminated body 1 formed of dielectric ceramic material, a plurality two pairs of internal electrodes 6 and 7 are formed so as to oppose to each other through the ceramic layers. The internal electrodes 6 and 7 of each pair of those are extended out to the opposing edge surfaces of the naked laminated body 1, respectively, and are connected to the external electrodes 2 and 2 which are formed at respective edge portions of the naked laminated body 1.

In such the laminated capacitor, the opposing area between the internal electrodes 6 and 7 is reduced so as to decrease the capacitance value, by removing a part of naked laminated body 1 and cutting a portion of the internal electrodes 6 and 7 with the irradiation of the laser beam on the surface thereof. Thereby, the capacitance is so adjusted that the resonance frequency is fitted within a predetermined boundary value.

For improving an efficiency in a production process and in a trimming accuracy with the laminated capacitor mentioned in the above, at an initial stage of the trimming process in which there is great difference between the actual value in capacitance and the target value thereof, it is desired to reduce the electrostatic capacity abruptly, however, at a final stage of the trimming process in which the actual capacitance value approaches to the target value, to reduce the value of electrostatic capacity slowly. Namely, it is preferable to adjust the capacitance roughly at the initial stage of trimming process and to adjust it finely at the final stage thereof.

However, with such the laminated capacitor as mentioned in the above, the value of the electrostatic capacity decreases almost linearly depending on decrease in the opposing area of the trimming electrode, since a proportion or rate of reduction in the opposing area of the trimming electrode is almost proportional to that of the value of the electrostatic capacity. Therefore, it is impossible to fulfill the both requirements, i.e., the improvement in efficiency of the trimming process as well as in the trimming accuracy.

Further, with such the laminated capacitor as mentioned in the above, it is impossible to adjust the electrostatic capacity value by increasing the value thereof since the trimming always functions only to decrease the electrostatic capacity value. Therefore, excessive trimming is not permissible and it cannot be recovered again afterward. Furthermore, even in case that the laminated capacitor produced has the electrostatic capacity value which is only slightly smaller than the designed value due to some reasons, it must be destroyed or disposed since the electrostatic capacity value of it cannot be brought up to the target value thereof. Therefore, there is drawbacks that a yield rate or factor of the products becomes to be low and it brings troubles in that the laminated capacitor must be

removed from for replacement thereof.

SUMMARY OF THE INVENTION

The present invention is achieved for dissolving such the drawbacks in the conventional trimming technology for such the laminated capacitor.

A first object according to the present invention is to provide a laminated capacitor and a trimming process thereof, in which the proportion or rate of decreasing in the electrostatic capacity value of the laminated capacitor is greater than that of reducing in the area of the trimming electrode, at the initial stage of trimming, thereby enabling abrupt or sharp decrease in the electrostatic capacity value, on the other hand at the final stage of trimming when approaching to the target value of the electrostatic capacity, the rate of decreasing in the electrostatic capacity value of the laminated capacitor is smaller than that of reducing in the area of the trimming electrode, thereby enabling slow dull decrease in the electrostatic capacity value. Namely, the object is to provide a laminated capacitor and a trimming process thereof, with which the rough and fine adjustment in the capacitance thereof is possible, and thereby achieving improvement of the efficiency in the trimming process as well as the improvement in the trimming accuracy thereof.

A second object in accordance with the present invention is to provide a laminated capacitor and a trimming process thereof, in which the value of electrostatic capacity can be adjusted by the trimming, not only in a direction of decreasing but also in a direction of increasing in the electrostatic capacity value.

According to the present invention, for accomplishing the first object mentioned in the above, there is provided a laminated capacitor, wherein a plurality of internal electrodes 18a, 18b, 18c formed within a naked laminated body 13 are opposing to a trimming electrode 19 formed on a surface of the naked laminated body 13 so as to obtain electrostatic capacity, and the plurality of internal electrodes 18a, 18b, 18c differ from one another in area opposing to the trimming electrode 19. With such the construction, by removing the trimming electrode 19 in trimming process, from a portion where it is opposing to the more of the internal electrodes 18a, 18b, 18c toward another portion where it is opposing to the less of the internal electrodes 18a, 18b, 18c, the rough adjustment in the initial stage of the trimming process can be achieved, in which the electrostatic capacity is decreased at a large proportion or rate with respect to that of reducing in the area of the trimming electrode 19, as well as the fine adjustment in accordance with the progress of the trimming process, in which the electrostatic capacity is decreased at a small proportion or rate with respect to that of reducing in the area of the trimming electrode 19. Thereby, the improvement of the efficiency in the trimming process and the improvement in the trimming accuracy can be obtained.

Namely, in accordance with the present invention, there is provided a laminated capacitor having a naked laminated body 13 including internal electrodes and at least a pair of external electrodes 14 attached at end portions of said naked laminated body 13, comprising:

a plurality of adjusting internal electrodes 18a, 18b, 18c being formed within said naked laminated body 13 and conducted to one of said pair of external electrodes 14; and

a trimming electrode 19 being formed on or in vicinity of a surface of said naked laminated body 13 opposing to said plurality of adjusting internal electrodes 18a, 18b, 18c and conducted to the other of said pair of external electrodes 14, wherein said plurality of adjusting internal electrodes 18a, 18b, 18c differ from one another in area thereof opposing to said trimming electrode 19, respectively.

Further, according to the present invention, there is provided a laminated capacitor having a naked laminated body 13 including internal electrodes and a plurality of external electrodes 14 attached at end portions of said naked laminated body 13, comprising:

a plurality of adjusting internal electrodes 18a, 18b, 18c being formed within said naked laminated body 13 and conducted to one of said plurality of external electrodes 14 and 14;

a plurality of adjusting internal electrodes 18a, 18b, 18c being formed within said naked laminated body 13 and conducted to the other of said plurality of external electrodes 14 and 14; and

a trimming electrode 19 being formed on or in vicinity of a surface of said naked laminated body 13 opposing to said plurality of adjusting internal electrodes 18a, 18b, 18c and insulated from said plurality of external electrodes 14 and 14, wherein said plurality of adjusting internal electrodes 18a, 18b, 18c differ from one another in area thereof opposing to said trimming electrode 19, respectively.

In a case of trimming such the laminated capacitor, said trimming electrode 19 is removed in a direction from a portion where it is opposing to the more of said adjusting internal electrodes 18a, 18b, 18c toward another portion where it is opposing to the less of said adjusting internal electrodes 18a, 18b, 18c.

With the trimming process of the trimming electrode 19 in such a manner as mentioned in the above, since the portion of the trimming electrode where it is opposing to the more of said adjusting internal electrodes 18a, 18b, 18c is removed in the initial stage of the trimming process, the electrostatic capacity is decreased at the large proportion or rate with respect to that of the reduction in the area of the trimming electrode 19, thereby enabling the rough adjustment. On the other hand, in

accordance with the progress of the trimming process, the number of said adjusting internal electrodes 18a, 18b, 18c opposing to said trimming electrode 19 becomes less and the distance thereof to said trimming electrode 19 also becomes far, therefore, the electrostatic capacity is decreased at the small proportion or rate with respect to that of the reduction in the area of the trimming electrode 19, thereby enabling the fine adjustment.

On a while, as the most common measure for achieving the trimming process, it can be mentioned of irradiating a laser beam upon said trimming electrode 19.

Here, by arranging said plurality of adjusting internal electrodes 18a, 18b, 18c opposing to said trimming electrode 19 in such manner that the nearer to said trimming electrode 19, the narrower in the area thereof, the proportion or rate of changing in the electrostatic capacity with respect to the reduction in the area of the trimming electrode 19 can be increased.

Further, said plurality of adjusting internal electrodes 18a, 18b, 18c are different from one another in either length or in width thereof, thereby, said plurality of adjusting internal electrodes 18a, 18b, 18c differ from one another in the area thereof opposing to said trimming electrode 19, respectively.

It is preferable to form or laminate a protection layer 20 containing conductive material for forming said trimming electrode 19 and ceramic material for forming said naked laminated body 13 between said trimming electrode 19 and said naked laminated body 13. Thereby, the naked laminated body 13 can be prevented from being deoxidized due to the trimming by irradiation of the laser beam on the trimming electrode 19. If the naked laminated body 13 is deoxidized in the trimming process, it changes into a conductive body or semi-conductive body to cause reduction in insulating resistance, however, such the reduction in insulating resistance can be prevented by protecting the naked laminated body 13 from the deoxidization.

With provision of internal electrodes 15 and 16 opposing to each other without obtaining electrostatic capacity therebetween within said naked laminated body 13, together with said plurality of adjusting internal electrodes 18a, 18b, 18c, thereby, it is possible to include a capacitor having a fixed electrostatic capacity which is hardly influenced by the trimming of the trimming electrode 19.

For accomplishing the second object mentioned in the above, in accordance with the present invention, there is provided a trimming process, using the laminated capacitor having a trimming electrode 19 on or in vicinity of a surface of said naked laminated body 13 opposing to at least a pair of internal electrodes 18a, 18b, 18c formed within said naked laminated body 13, wherein a portion of an adjusting layer 21 laminated between said trimming electrode 19 and said internal electrode 18 is deoxidized in a part thereof by irradiation of a laser beam on said trimming electrode 19. Thereby, said trimming electrode 19 and one of said internal electrode 18 are short-circuited therebetween. With the trimming process of this, it is possible to adjust the electrostatic capacity of the laminated capacitor in a direction for increasing it.

Further, upon the irradiation of the laser beam, the adjusting layer 21 is removed and deoxidized by the irradiation of the same laser beam to be turned into the conductive body. With this, the distance from the trimming electrode 19 to the opposing internal electrodes 18a, 18b, 18c is decreased substantially, thereby adjusting the electrostatic capacity of the laminated capacitor in a direction for decreasing it, in the same manner.

Namely, according to the present invention, a laminated capacitor having a naked laminated body 13 including internal electrodes 18a, 18b, 18c, external electrodes 14 attached at end surfaces of said naked laminated body 13, a trimming electrode 19 formed on or in vicinity of said naked laminated body 13 opposing to at least a pair of internal electrodes 18a, 18b, 18c which are formed within said naked laminated body 13, and an adjusting layer 21 which is deoxidized by irradiation of a laser beam onto said trimming electrode 19 is provided between said trimming electrode 19 and said internal electrode 18a.

And, in a trimming process of this laminated capacitor, said adjusting layer 21 is deoxidized in a part thereof by the irradiation of the laser beam on said trimming electrode 19, thereby conducting between said adjusting layer 21 and said a part of said internal electrode 18a. Then, the series connection of a pair of capacitors of the laminated capacitor through the trimming electrode 19 in the equivalent circuit thereof before the trimming process, is changed into a single capacitor, and the value of the conductance becomes about as two times large as that before the trimming. Namely, it is possible to achieve the trimming in a direction for increasing the electrostatic capacity. Because of this, in a case that the electrostatic capacity comes to be excessively small due to failure in the trimming process, or in a case that the electrostatic capacity of a capacitor produced is smaller than the desired value in designing it, the electrostatic capacity thereof can be increased by the trimming mentioned in the above so as to recover it.

Moreover, in the trimming process of the laminated capacitor, it is also possible to achieve the trimming in the direction of increasing the electrostatic capacity of the laminated capacitor by deoxidizing said adjusting layer 21 and removing it as well with the irradiation of the laser beam. Namely, when the adjusting layer 21 below the trimming electrode 19 on which the laser beam is irradiated is removed and deoxidized in a part thereof to be turned into the conductive body, the distance between said trimming electrode 19 and said internal electrodes 18a, 18b, 18c is narrowed substantially. Therefore, the electrostatic capacity of the laminated capacitor is increased. With this trimming

process, in comparison with the above-mentioned trimming process in which said trimming electrode 19 and said the internal electrode 18a are conducted to each other by short-circuiting therebetween, the electrostatic capacity value which can be increased thereby is small. Therefore, it is effective only in a case of no necessity for drastic increase in the electrostatic capacity value thereof.

For turning the adjusting layer 21 into the conductive body by the deoxidization thereof, it is effective that valence controlling material is contained in a boundary surface between said trimming electrode 19 and said adjusting layer 21. Furthermore, such the valence controlling material can be contained in the naked laminated body 13, in particular, in the portion of said adjusting layer in advance.

Further, after increasing the electrostatic capacity of the laminated capacitor in the manner mentioned in the above, it is also possible to remove said trimming electrode 19 by irradiating another laser beam thereon, which is smaller in output power than that of said laser beam for the trimming mentioned in the above, without deoxidizing said adjusting layer 21. Because of this, the opposing area between said trimming electrode 19 and said internal electrodes 18a, 18b, 18c without being conducted with said trimming electrode 19 is reduced down, thereby, on the contrary to the above, enabling the adjustment in the electrostatic capacity in the direction of decreasing the value thereof.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 (a) and (b) are vertical cross-sectional side views for showing conditions in an example of a laminated capacitor in accordance with the present invention before and after a trimming process;

Fig. 2 is a top plane view for showing a condition in the example of the same laminated capacitor after the trimming process;

Fig. 3 is an exploded perspective view for showing laminated construction of a naked laminated body in the example of the same laminated capacitor;

Fig. 4 is an enlarged cross-sectional view for showing a portion A in Fig. 1;

Fig. 5 is a vertical cross-sectional side view for showing a condition in another example of the same laminated capacitor in accordance with the present invention before the trimming process;

Fig. 6 is a vertical cross-sectional side view for showing a condition in further another example of the same laminated capacitor in accordance with the present invention before the trimming process;

Fig. 7 is graphs for showing relationships between proportion in reducing in area of trimming electrode and that of electrostatic capacity in the example of the above-mentioned capacitor and an example for comparison;

Fig. 8 is a vertical cross-sectional side view for showing a condition in an example of a laminated capacitor in accordance with the conventional art before the trimming process;

Fig. 9 is a vertical cross-sectional side view for showing a condition in another example of another laminated capacitor in accordance with the conventional art after the trimming process;

Fig. 10 is a vertical cross-sectional side view for showing a condition in further another example of the same laminated capacitor in accordance with the present invention before the trimming process;

Figs. 11 (a) and (b) are vertical cross-sectional side views for showing conditions in the example for comparison of the above-mentioned laminated capacitor before and after the trimming process;

Fig. 12 is a vertical cross-sectional top view for showing a condition in further another example of the same laminated capacitor in accordance with the present invention before the trimming process;

Fig. 13 is a vertical cross-sectional top view for showing a condition in an example of the same laminated capacitor in accordance with the present invention after treating the trimming for increasing the electrostatic capacity thereof; and

Fig. 14 is a vertical cross-sectional top view for showing a condition in another example of the same laminated capacitor in accordance with the present invention after treating the trimming process for increasing the electrostatic capacity thereof.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, detailed explanation of the embodiments according to the present invention will be given by referring to attached drawings.

First of all, a ceramic slurry is prepared by dispersing power of ceramic ingredient, such as BaO-TiO2-Nd2O3, into an organic binder dissolved in a solvent with uniformity, then it is pasted on a base film of polyethylene terephthalete, etc., with a thin and uniform thickness and is dried up to form a film-like ceramic green sheet therefrom. After this, the green sheet is cut into pieces of appropriate sizes.

Next, an internal electrode is printed on a surface of each of the cut green sheets. The green sheets printed with the internal electrode pattern are piled up one another, and further the green sheets printed with no such the internal electrode pattern, i.e., so-called dummy sheets are piled up on both sides of it. And, they are pressed to be closely contacted to one another so as to obtain a laminated body therewith. The laminated body obtained is cut in vertical and horizontal directions to obtain each chip-like laminated body. Thereafter, by baking the laminated body, a principal or naked laminated body being baked.

The naked laminated body 13 is constructed with ceramic layers 11, 11... piled up in a plurality thereof,

each of which is made of dielectric material without such the internal electrode as shown in Fig. 3, and further thereon is piled up with ceramic layers 12a, 12b, 12c on which surfaces are printed internal electrodes 18a, 18b, 18c for adjusting. And, further on both sides of it, ceramic layers 17, 21 without being formed with the internal electrode are piled up respectively. As to the adjusting internal electrodes 18a, 18b, 18c, those which are formed on the ceramic layers 12a, 12b at an upper side are shorter than those formed on the ceramic layers 12b, 12c at a lower side thereof. Those adjusting electrodes 18a, 18b, 18c are extended out onto an end surface of the naked laminated body 13. Further, the ceramic layer at the top of it is to be as an adjusting layer 21.

A trimming electrode 19 is formed on the surface of the naked laminated body 13, i.e., on the ceramic layer to be as the adjusting surface 21. In more detail, first of all, such a protection layer 20 as shown in Fig. 4 is formed by printing a paste of mixture including the powder of conductive component such as Pd, etc., and the same ceramic powder to that of forming the naked laminated body 13, and then being baked. Next, on the surface of it, conductive paste including powder of conductive material such as Pd is printed and baked to form a thick conductive layer 22. Further on it, the surface is treated with Au plating to form a thin conductive layer 23. Those thick conductive layer 22 and thin conductive layer 23 form together a trimming electrode 19. Further, the thick conductive layer 22 can be provided in the vicinity of the surface of naked laminated body 13 in the inside thereof, under the condition that it is covered with a thin ceramic film or other insulating layer. However, in that case, it is impossible to form the thin conductive layer 23.

As is apparent from Fig. 2, the trimming electrode 19 is formed so as to be extended outside onto an end surface of the naked laminated body 13, on the opposing end surface of which are extended outside the adjusting internal electrodes 18a, 18b, 18c.

Moreover, as shown in Fig. 1(a), a conductive paste, such as Ag paste, is pasted on both of those end surfaces of the naked laminated body 13, onto which surfaces are extended outside the adjusting internal electrodes 18a, 18b, 18c and the trimming electrode 19, respectively. This is baked to be formed with external electrodes 14 and 14. Thereby, it is completed as a laminated capacitor. One of those external electrodes 14 and 14 is conducted to the adjusting internal electrodes 18a, 18b, 18c, and the other thereof to the trimming electrode 19.

In this embodiment, though the trimming electrode 19 and the external electrodes 14 and 14 are formed separately from each other, however, they can be formed at the same time and of the same material.

With the laminated capacitor of such the construction, since the trimming electrode 19 is confronting or opposing to the plurality of the adjusting internal electrodes 18a, 18b, 18c, therefore, electrostatic capacity can be obtained between the external electrodes 14 and 14. Each of the plurality of adjusting internal electrodes 18a, 18b, 18c has respective area opposing to the trimming electrode 19, being different to one another, for instance, the nearer to the trimming electrode 19, the smaller in the area, in the embodiment. In other words, with those adjusting electrodes 18a, 18b, 18c, the farther from the trimming electrode 19, the greater in the area opposing to that trimming electrode 19.

Further, those adjusting internal electrodes 18a, 18b, 18c can be different not only in the length but also in the width thereof.

In the trimming method of the laminated capacitor, as shown by an arrow in Fig. 1(b), a laser beam is irradiated upon a portion of the trimming electrode 19. Thereby, as shown in Fig. 1 (b) and Fig. 2, the portion of the trimming electrode 19 is removed. At this time, the trimming electrode 19 is removed from the top portion opposing to many of the adjusting internal electrodes 18a, 18b, 18c toward the base portion which is conducted to the external electrode 14. The portion of the trimming electrode 19 which is removed from is shown by a two-dotted line in Fig. 1 (b) and Fig. 2.

By doing so, the opposing area where the trimming electrode 19 and the each adjusting electrode 18a, 18b, 18c are facing or opposing to is reduced as well as in the number thereof. Thereby, at an initial stage of the trimming process, a proportion or rate of reducing in the electrostatic capacity is relative large with respect to that rate of the trimming electrode 19. The number of those adjusting electrode 18a, 18b, 18c opposing to the trimming electrode 19 is decreased in accordance with the progress of the trimming process, and the distances of them opposing to the trimming electrode 19 becomes longer, therefore, the rate of reducing in the electrostatic capacity comes to be small gradually with respect to that rate of the trimming electrode 19.

A graph depicted by a solid line in Fig. 7 shows an example of a relationship between the rate of reducing in the area of the trimming electrode 19 and that rate of the electrostatic capacity thereof, when the trimming electrode 19 of the laminated capacitor is treated with the trimming process in the manner mentioned in the above. It is indicated by assuming that the area of the trimming electrode 19 and the electrostatic capacitor are at 100% before the trimming process is started.

Further, a graph depicted by a broken line in Fig. 7 shows an example of a relationship between the rate of reducing in the area of the trimming electrode 19 and that of the electrostatic capacity thereof, when the trimming electrode 19 of the laminated capacitor is treated with the trimming process, in the same manner as mentioned in the above, by using the laminated capacitor as shown in Fig. 11 (a) for comparison, in the manner as shown in Fig. 11(b). In this comparison, the internal adjusting electrode 18 is single.

As apparent from the graphs shown in Fig. 7, with the exemplar of the capacitor for comparison of the latter shown by the broken line therein, the rate of reducing in the area of the trimming electrode 19 is almost completely proportional to that of the electrostatic capacity thereof when the trimming electrode 19 of the laminated capacitor is treated with the trimming process, and it changes linearly. Contrary to this, with the exemplar of the former in accordance with the present invention as shown by the solid line therein, the rate of reducing in the area of the trimming electrode 19 is not proportional to that of the electrostatic capacity thereof when the trimming electrode 19 of the laminated capacitor is treated with the trimming process. Namely, the reducing rate in the electrostatic capacity is large at the initial stage of the trimming process, and it decreased in accordance with the progress of the trimming process.

A laser beam which is used for the trimming process is preferably to have a wavelength less than that of a visible ray of light, such as an excimer laser, etc. With this, the naked laminated body 13 can be protected from deoxidization during the trimming process. Further, the protection layer 20 (see Fig. 4) provided between the trimming electrode 19 and the naked laminated body 13 functions as a damper band with respect to the laser beam so as to prohibit the naked laminated body 13 from the deoxidization. Moreover, for the trimming process, not only such the laser beam, but also is applicable a mechanical process, such as sandblasting or other method.

In an another example of the laminated capacitor which is shown in Fig. 5, at least a pair of internal electrodes 15 and 16 are provided in the naked laminated body 13, opposing to each other through the dielectric ceramic layer thereof, and they are extended outside onto the end surfaces of the naked laminated body 13 opposing to each other, respectively, thereby conducting with the external electrodes 14 and 14.

An aspect that the trimming electrode 19 and the plurality of internal adjusting electrodes 18a, 18b, 18c opposing thereto are formed within the naked laminated body 13 and other aspects are the same to that of the example as previously mentioned in the above. Further, the trimming process is also the same to that mentioned in the above.

This laminated capacitor can be presented by an equivalent circuit in which the electrostatic capacity obtained by opposing the internal electrodes 15 and 16 to each other through the dielectric ceramic layer and that obtained by opposing of the trimming electrode 19 and the adjusting internal electrodes 18a, 18b, 18c are connected in parallel through the external electrodes 14 and 14. Since the internal electrodes 15 and 16 are provided, being biased to the opposing side at which the trimming electrode 19 is formed, and are apart from the trimming electrode 19, they hardly form the electrostatic capacity between the same trimming electrode 19. Therefore, the electrostatic capacity which is obtained by trimming of the trimming electrode 19 opposing to the internal electrodes 15 and 16 is hardly changed, thereby obtaining a fixed electrostatic capacity.

In a further another example of the laminated capacitor shown in Fig. 6, the trimming electrode 19 which is formed on a surface of the naked laminated body 13 is not conducted with the external electrode 14 and 14 thereof, thereby they are provided in the condition of being insulated. Further, two sets of the adjusting internal electrodes 18a, 18b, 18c are provided in an inside of the naked laminated body 13, and each set of the adjusting internal electrodes 18a, 18b, 18c is conducted to the respective other external electrodes 14 and 14 which are provided on the opposing end surfaces of the naked laminated body 13. The farther one of the adjusting internal electrodes 18a, 18b, 18c from the trimming electrode 19, the longer in the length thereof, thereby being larger as much in the area which is opposing to the trimming electrode 19. Other aspects than that are the same to those of the example mentioned in the above.

This laminated capacitor can be presented by an equivalent circuit in which the electrostatic capacities obtained among the trimming electrode 19 and the two sets of adjusting internal electrodes 18a, 18b, 18c are connected in series through the trimming electrode 19.

Also of this laminated capacitor, the laser beam is irradiated upon the trimming electrodes 19 so as to remove it by the trimming process, from the right-hand side edge or the left-hand side edge up to the center portion thereof in Fig. 6. With this, in the same manner to that of the example mentioned in the above, the rate of reducing in the electrostatic capacity is large with respect to that of the trimming electrode 19 at the initial stage of the trimming process, and it gradually decreases in accordance with the progress of the trimming process.

In a further other example of the laminated capacitor shown in Fig. 10, although the adjusting internal electrodes 18a, 18b, 18c are different in the length thereof in any one of those examples mentioned in the above, they are different one another in the width thereof. Those internal electrodes 18a, 18b, 18c are conducted to one of the external electrodes 14 of the naked laminated body 13. The farther one of the adjusting internal electrodes 18a, 18b, 18c from the trimming electrode 19, the wider in the width thereof, thereby being larger as much in the area which is opposing to the trimming electrode 19. Other aspects than that are the same to those of the example mentioned in the above.

With such the laminated capacitor, it is preferable to remove the trimming electrode 19 by the trimming process from the left-hand side towards right-hand side in Fig. 10. By conducting the trimming process in this manner, it is possible to change the rate of reducing in the electrostatic capacity in such manner that it is large at the initial stage of the trimming process and it gradu-

ally decreases in accordance with the progress of the trimming process.

Further, the adjusting internal electrodes 18a, 18b, 18c can be changed not only in the width but also in the length thereof.

Fig. 12 shows a further other example of the laminated capacitor. Although all the adjusting internal electrodes 18a, 18b, 18c are conducted to the one external electrode 14 by contacting therewith in the example shown in Fig. 1, however, in this example, the adjusting internal electrodes 18a, 18b, 18c are conducted to one another through so-called a through-hole conductor 22 penetrating through the ceramic layer of the naked laminated body 13. In such the laminated capacitor, it is not necessary that all the adjusting internal electrodes 18a, 18b, 18c are contacted with the one external electrode 14, and in the example in Fig. 12, only one adjusting internal electrode 18a is contacted with the external electrode 14. The other adjusting internal electrodes 18b, 18c are conducted to the external electrode 14 through the through-hole conductor 22.

Also with such the laminated capacitor, it is possible to change the rate of reducing in the electrostatic capacity in such manner that it is large at the initial stage of the trimming process and it gradually decreases in accordance with the progress of the trimming process, by trimming the trimming electrode 19, in the same manner as in the laminated capacitor in Fig. 2 which is mentioned in the above.

Next, a trimming process for recovery will be explained, in particular, if the trimming electrode 19 of the laminated capacitor is treated by the trimming and the electrostatic capacity thereof is reduced down too much comparing to a desired value thereof.

For example, as shown in Fig. 1(b), when the electrostatic capacity is decreased down for the desired value thereof, as the result of the excessive trimming of the trimming electrode 19 of the laminated capacitor, a laser beam from a Nd-YAG laser, etc., is irradiated upon an edge portion of the trimming electrode 19 which has been treated by the trimming process. According to this, as shown in Fig. 13, an adjusting layer 21 of the trimming electrode 19 is deoxidized in a part thereof to be turned into conductive, thereby the trimming electrode 19 and the internal electrode 18a being short-circuited. A reference numeral 20 indicates that short-circuited portion. With this portion, the internal electrode 18a and the trimming electrode 19 are short-circuited, thereby the capacity obtained between the trimming electrode 19 and the internal electrode 18 is about doubled, comparing to that of the capacitor before the trimming process. Namely, the electrostatic capacity defined between the external electrodes 14 and 14 increases as much.

For making the deoxidization of the adjusting layer 21 easy by the irradiation of the laser beam, a valence controlling material can be included in at least in the trimming electrode 19 or in a boundary surface between the trimming electrode 19 and the adjusting layer 21. For instance, an oxide of a metal which has a valence larger than that of the metal contained in the ceramic material is added. That is, an oxide of Nb of a pentavelenct (5-valent) metal is added for Ti of a tetravalent (4-valent) metal in $BaTiO_3$, or an oxide of La of a trivalent (3-valent) metal is added to Ba of a divalent (2-valent) metal. Thereby, since free electron is generated in the adjusting layer 21 when the trimming is treated upon it, it is turned into conductive easily.

Further, such the valence controlling material as mentioned in the above can be added into the ceramic material for forming the naked laminated body 13 in advance. Further, this valence controlling material can be added to only the ceramic green sheet for forming the adjusting layer 21. In this case, the valence controlling material to be added to the ceramic material is 0.5 mol% at the most, and ordinarily, it can be added at 0.05 mol% and more or less.

After increasing the electrostatic capacity of the laminated capacitor in this way, for decreasing the electrostatic capacity value thereof, the laser beam is irradiated onto the trimming electrode 19 to remove it in a part thereof. Thereby, the area where the trimming electrode 19 and the internal electrode 18 are opposing to each other is reduced and the electrostatic capacity defined therebetween is also decreased down. In this moment, since the trimming electrode 19 is not short-circuited, it is important that the trimming process is carried out by setting laser beam at the output power lower than that during the trimming process mentioned in the above, for the purpose of preventing the internal electrode 18 and the trimming electrode 19 from being short-circuited to each other. For example, it is possible to remove the trimming electrode 19 without heating it so much, by using a laser beam of wavelength shorter than that of the visible ray light, such as of the excimer laser, etc., as the laser beam for use in the trimming process. Therefore, the area of only the trimming area 19 can be reduced without causing deoxidization in the adjusting layer 21. Further, since this trimming process is treated only for the purpose of reducing the trimming electrode 19, it can be replaced by another trimming process, such as the sandblasting, etc.

Next, another trimming method of the laminated capacitor is shown in Fig. 14. In this method of trimming of the laminated capacitor, the laser beam from such as the Nd-YAG laser, etc. is irradiated upon a part of the trimming electrode 19. By this, as shown in Fig. 15, a portion of the adjusting layer 21 is removed as well as it is deoxidized to be turned into conductive. A reference numeral 23 shows the conductive layer which is partially changed into electrically conductive body in the removed portion.

With this, as shown in Fig. 14, the distance between the internal electrode 18a and the trimming electrode 19 is substantially narrowed. As a result of this, the capacity obtained between the trimming electrode 19 and the internal electrode 18a becomes larger than that of

before the trimming thereof, thereby increasing the electrostatic capacity between the external electrodes 14 and 14 as much.

Thereafter, if necessary, such the trimming process for decreasing the area of the trimming electrode 19 as mentioned in the above is conducted.

The features disclosed in the foregoing description, in the claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realising the invention in diverse forms thereof.

## Claims

1. A laminated capacitor having a naked laminated body (13) including internal electrodes and at least a pair of external electrodes (14) attached at end portions of said naked laminated body (13), comprising:

   a plurality of adjusting internal electrodes (18a), (18b), (18c) being formed within said naked laminated body (13) and conducted to one of said pair of external electrodes (14); and
   a trimming electrode (19) being formed on or in vicinity of a surface of said naked laminated body (13) opposing to said plurality of adjusting internal electrodes (18a), (18b), (18c) and conducted to the other of said pair of external electrodes (14), wherein said plurality of adjusting internal electrodes (18a), (18b), (18c) differ from one another in area thereof opposing to said trimming electrode (19) respectively.

2. A laminated capacitor having a naked laminated body (13) including internal electrodes and a plurality of external electrodes (14) attached at end portions of said naked laminated body (13), comprising:

   a plurality of adjusting internal electrodes (18a), (18b), (18c) being formed within said naked laminated body (13) and conducted to one of said plurality of external electrodes (14), (14);
   a plurality of adjusting internal electrodes (18a), (18b), (18c) being formed within said naked laminated body (13) and conducted to the other of said plurality of external electrodes (14), (14); and
   a trimming electrode (19) being formed on or in vicinity of a surface of said naked laminated body (13) opposing to said plurality of adjusting internal electrodes (18a), (18b), (18c) and insulated from said plurality of external electrodes (14), (14), wherein said plurality of adjusting internal electrodes (18a), (18b), (18c) differ from one another in area thereof opposing to said trimming electrode (19) respectively.

3. A laminated capacitor as described in Claim 1 or 2, wherein said plurality of adjusting internal electrodes (18a), (18b), (18c) opposing to said trimming electrode (19) are arranged in such manner that the nearer to said trimming electrode (19), the narrower in the area thereof.

4. A laminated capacitor as described in Claim 1 or 2, wherein said plurality of adjusting internal electrodes (18a), (18b), (18c) are different from one another in length thereof.

5. A laminated capacitor as described in Claim 1 or 2, wherein said plurality of adjusting internal electrodes (18a), (18b), (18c) are different from one another in width thereof.

6. A laminated capacitor as described in Claim 1 or 2, wherein a protection layer (20) containing conductive material for forming said trimming electrode (19) and ceramic material for forming said naked laminated body (13) is laminated between said trimming electrode (19) and said naked laminated body (13).

7. A laminated capacitor as described in Claim 1 or 2, wherein internal electrodes (15), (16) opposing to each other without obtaining electrostatic capacity therebetween are provided within said naked laminated body (13) together with said plurality of adjusting internal electrodes (18a), (18b), (18c).

8. A trimming process of said laminated capacitor as described in Claim 1 or 2, wherein said trimming electrode (19) is removed from a portion where it is opposing to the more of said adjusting internal electrodes (18a), (18b), (18c) toward another portion where it is opposing to the less of said adjusting internal electrodes (18a), (18b), (18c).

9. A trimming process of said laminated capacitor as described in Claim 8, wherein said trimming electrode (19) is removed by irradiating a laser beam thereon.

10. A laminated capacitor as described in Claim 1 or 2, wherein, with said trimming electrode (19), an adjusting layer (21) which is deoxidized by irradiation of a laser beam onto said trimming electrode (19) is provided between said trimming electrode (19) and said internal electrode (18).

11. A laminated capacitor as described in Claim 10, wherein said adjusting layer (21) forms a layer which is deoxidized and removed by the irradiation of the laser beam.

12. A laminated capacitor as described in Claim 1 or 2, wherein valence controlling material is contained in a boundary surface to said trimming electrode (19) or between said trimming electrode (19) and said adjusting layer (21).

13. A laminated capacitor as described in Claim 1 or 2, wherein valence controlling material is contained in at least said adjusting layer (21) of said naked laminated body (13).

14. A trimming process for adjusting electrostatic capacity value of a laminated capacitor having a naked laminated body (13) including internal electrodes (15), (16), (18) and external electrodes (14) attached at end surfaces of said naked laminated body (13), by trimming thereof, comprising steps of:

preparing the laminated capacitor having a trimming electrode (19) formed on or in vicinity of a surface of said naked laminated body (13) opposing to at least a pair of said internal electrodes (18) formed within said naked laminated body (13), and an adjusting layer (21) provided between said trimming electrode (19) and said internal electrodes (18) and to be deoxidized by irradiation of a laser beam on said trimming electrode (19); and
irradiating the laser beam on said trimming electrode (19) so as to deoxidize said adjusting layer (21) in a part thereof.

15. A trimming process of a laminated capacitor as described in Claim 14, wherein said adjusting layer (21) is deoxidized in a part thereof and removed by the irradiation of the laser beam.

16. A trimming process of a laminated capacitor as described in Claim 15, wherein, after the removal of said adjusting layer (21) by the irradiation of the laser beam on said trimming electrode (19), said trimming electrode (19) is removed by irradiating another laser beam which is smaller in output power than that of said laser beam thereon, thereby removing said trimming electrode (19) without deoxidizing said adjusting layer (21).

17. A laminated capacitor having a naked laminated body (13) including internal electrodes (15), (16), (18) and external electrodes (14) attached at end portions of said naked laminated body (13), comprising:

a trimming electrode (19) formed on or in vicinity of a surface of said naked laminated body (13) opposing to at least a pair of said internal electrodes (18) which is formed within said naked laminated body (13); and
an adjusting layer (21) to be deoxidized by irradiation of a laser beam and positioned between said trimming electrode (19) and said internal electrodes (18), wherein said adjusting layer (21) is deoxidized in a part thereof by the irradiation of the laser beam on said trimming electrode (19), thereby said trimming electrode (19) and a part of said internal electrode (18) are conducted to each other.

18. A laminated capacitor having a naked laminated body (13) including internal electrodes (15), (16), (18) and external electrodes (14) attached at end portions of said naked laminated body (13), comprising:

a trimming electrode (19) formed on or in vicinity of a surface of said naked laminated body (13) opposing to at least a pair of said internal electrodes (18) which is formed within said naked laminated body (13); and
an adjusting layer (21) to be deoxidized by irradiation of a laser beam and positioned between said trimming electrode (19) and said internal electrodes (18), wherein said adjusting layer (21) is removed in a part thereof and deoxidized by the irradiation of the laser beam on said trimming electrode (19), thereby being conductive body.

Fig1

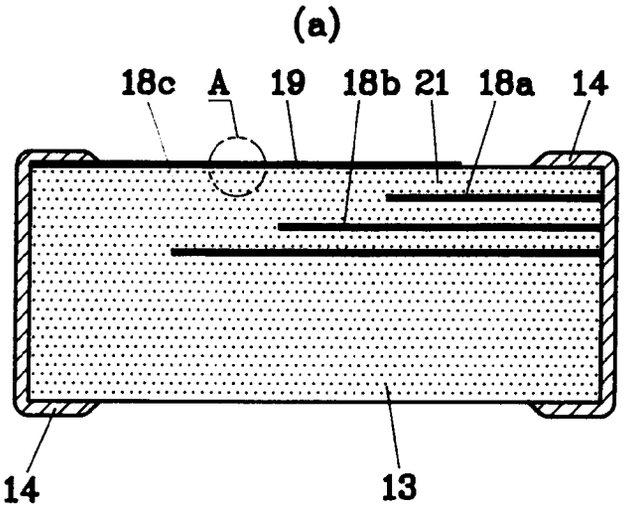



Fig. 2

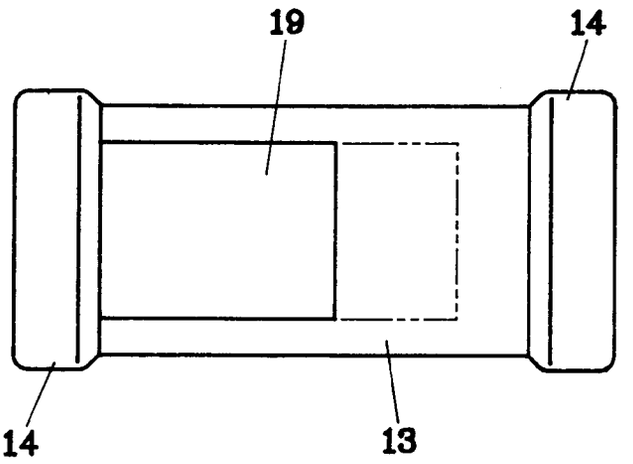


Fig. 3

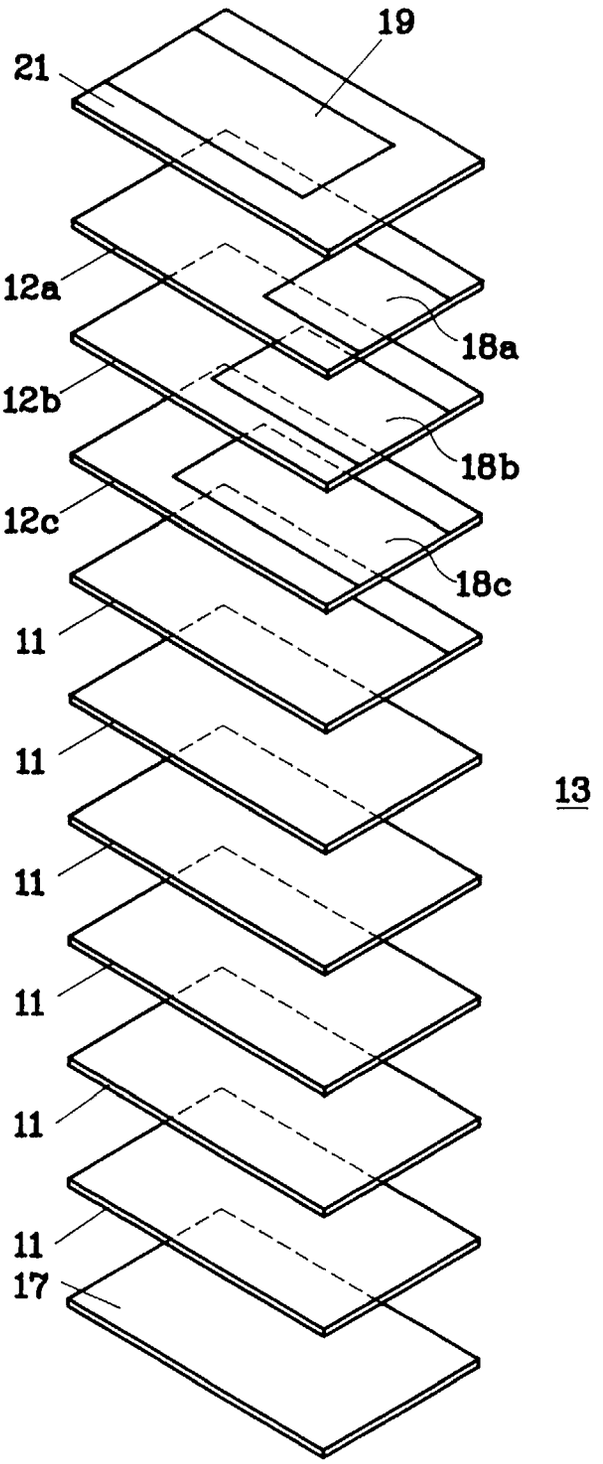


Fig. 4

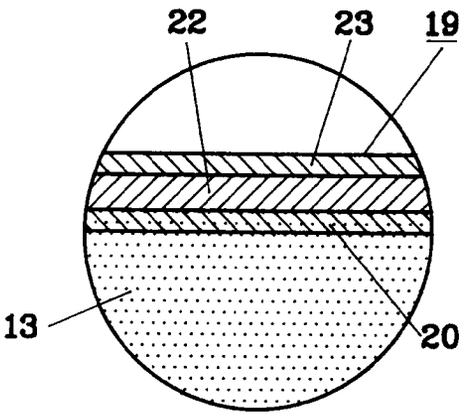



Fig. 5

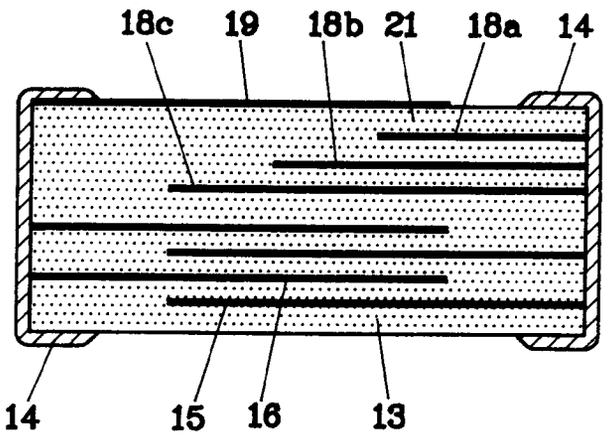



Fig. 6

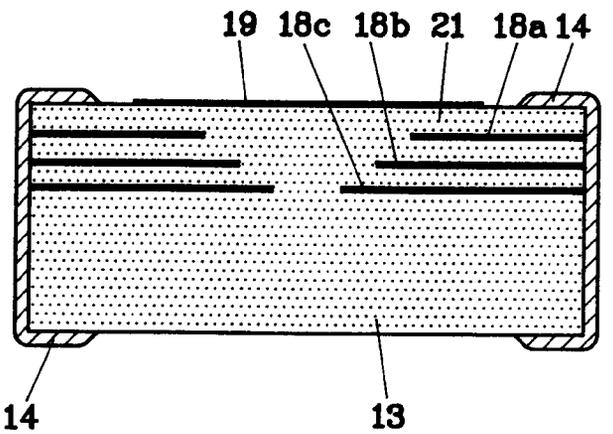


Fig. 7

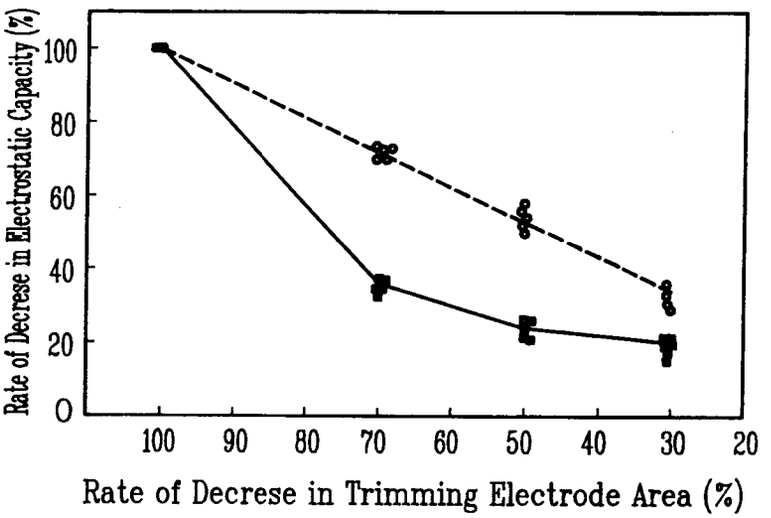



Fig. 8
(Prior Art)

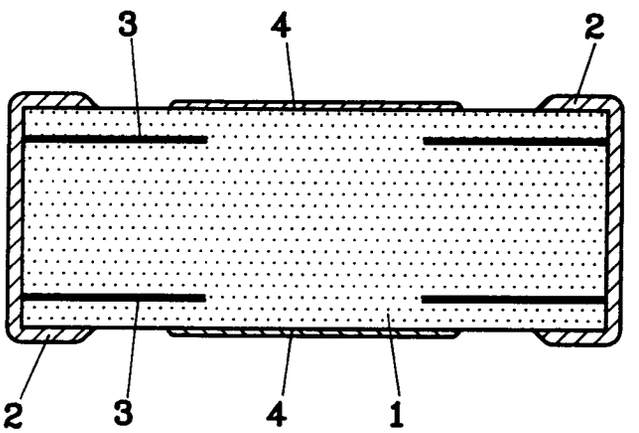



Fig. 9
(Prior Art)

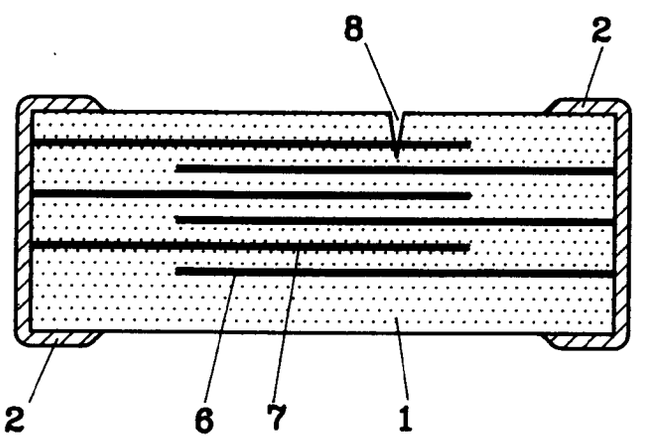


Fig. 10

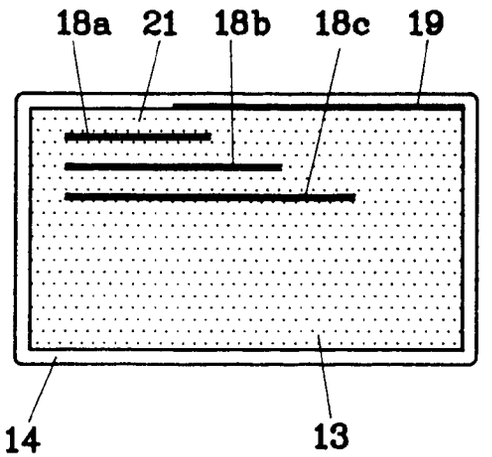
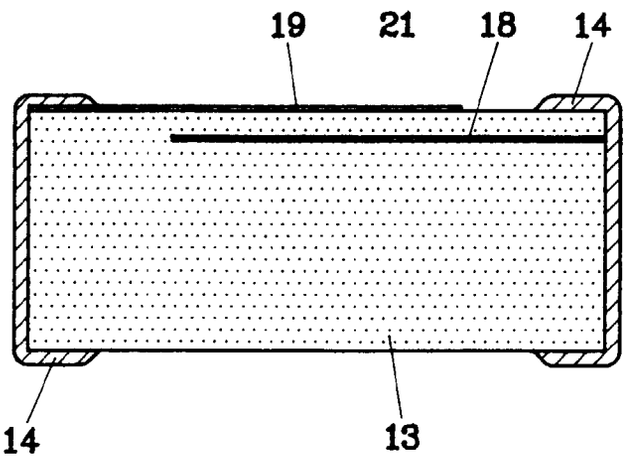



Fig. 11

(a)




(b)

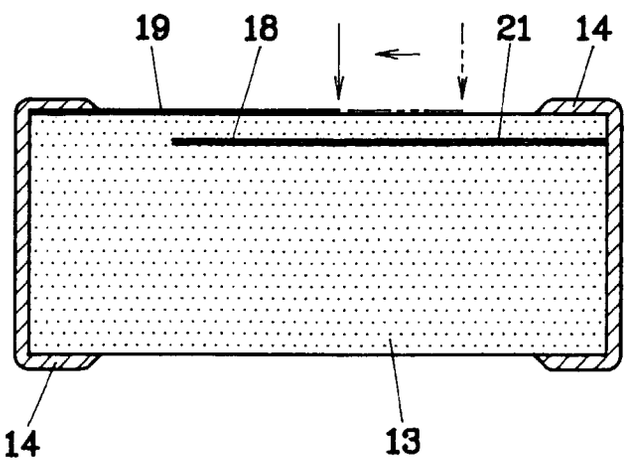


Fig12

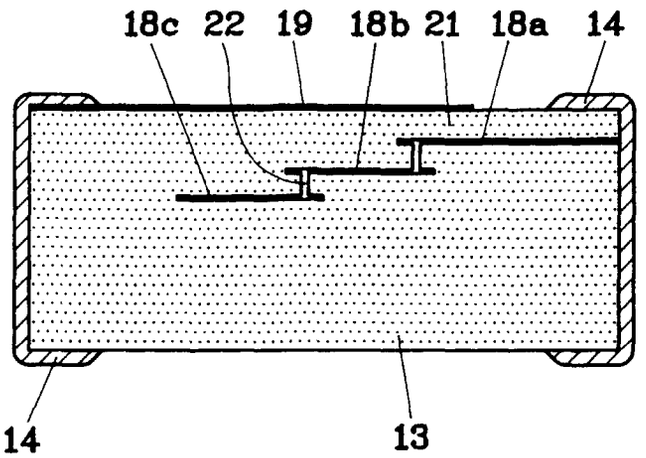



Fig13

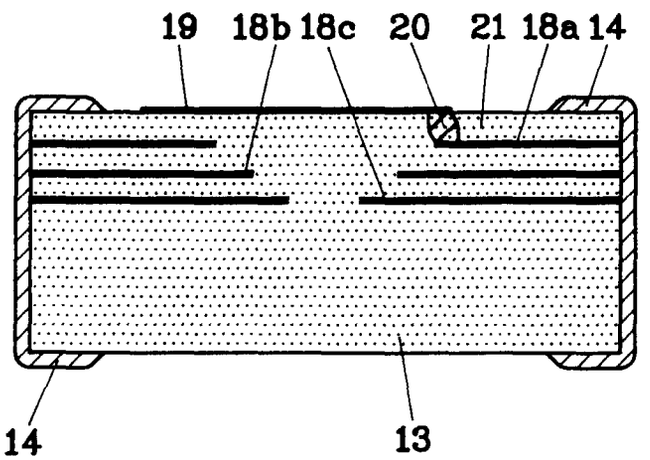
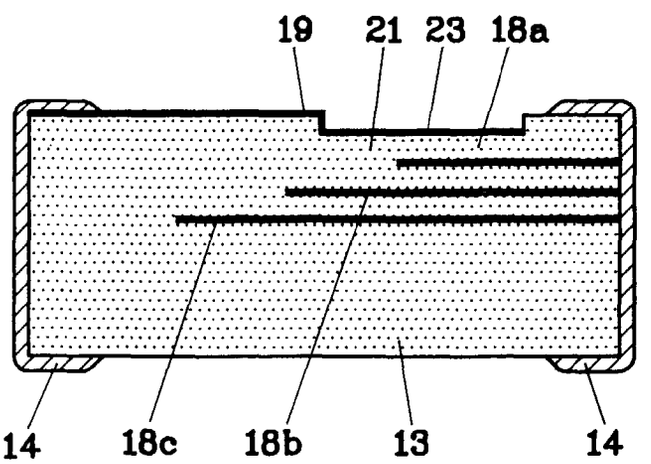



Fig.14



European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 98 10 2290

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
|---|---|---|---|
| A | PATENT ABSTRACTS OF JAPAN vol. 17, no. 613 (E-1458), 11 November 1993 & JP 05 190379 A (MURATA MFG CO LTD), 30 July 1993, * abstract * | 1,14-16, 18 | H01G4/255 |
| A | PATENT ABSTRACTS OF JAPAN vol. 14, no. 457 (E-0986), 2 October 1990 & JP 02 185007 A (MURATA MFG CO LTD), 19 July 1990, * abstract * | 17 | |
| D,A | PATENT ABSTRACTS OF JAPAN vol. 95, no. 10, 30 November 1995 & JP 07 183162 A (TDK CORP), 21 July 1995, * abstract * | | |
| D,A | PATENT ABSTRACTS OF JAPAN vol. 95, no. 5, 30 June 1995 & JP 07 045469 A (MURATA MFG CO LTD), 14 February 1995, * abstract * | | TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01G |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 3 June 1998 | Goossens, A |

CATEGORY OF CITED DOCUMENTS

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